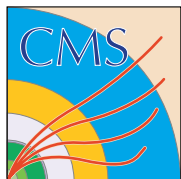**PRS: Physics Reconstruction and Selection**
HCAL/JetsMET group

Status of JetsMET

Shuichi Kunori

U. of Maryland

06-June-2001

Scope of the PRS project

P ■ The PRS groups will work on (and will also have responsibility for) the following tasks:

- ◆ Detector simulation
- ◆ Detector reconstruction
- ◆ Detector calibration
- ◆ Monitoring
- ◆ Physics object reconstruction and selection (HLT)
- ◆ Test beam analysis

4 groups
- JetMET
- egamma
- muon
- b/tau

C ■ CoreSW/Comp will carry all other (offline) software not included above.

T ■ Ditto for Trigger/DAQ (but scope of overlap is online farm and framework)

First CPT week was in April, 2001.

HCAL - Jets/MET

S.Eno / S.Kunori - Coordinator

http://home.fnal.gov/~sceno/jpg/Default.htm

Dates:

End 2002 DAQ TDR (end 2001 for HLT section)

End 2004 Physics TDR

Organization:

HCAL simulation – Sunanda Banerjee (TIRF)

CMSIM/GEANT4/FAST

Verify shower model in G4.

Calibration & Monitoring – Olga Kodolova (MSU)

energy scale of jets, MET, tau

-> from detector construction/commission to in-situ calibration.

HCAL in ORCA – Salavat Abdoullin (Maryland)

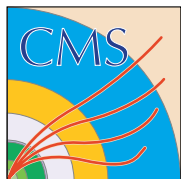readout simulation + …

Physics objects with HCAL – Sasha Niketenko (CERN/ITEP)

jets, MET & tau

DAQ TDR

- Currently, the DAQ TDR has one chapter dedicated to the High Level Trigger
  - It should describe:
    - Amount of data per detector (occupancies, etc)
    - Readout scheme (zero-suppression, selective readout etc)
    - Basic raw data format (time samples)
    - Basic reconstruction
    - Lvl-2 algorithms
    - Lvl-3 algorithms
    - Performance of all object identification
    - Basic trigger table that includes all discovery channels
    - Basic rate plots. We MUST have a credible scenario to get to the O(100) Hz level

For both low and high luminosity

A lot of work needed !
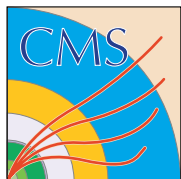
Main Issues

Many physics analyses require

- low E_T jets:

> **from top, W, Higgs**
> **from WW fusion**

> **part of signal**
> **background rejection (e.g. jet veto)**

- High luminosity

> **pile-up energy**
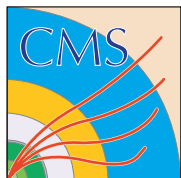> **low ET jets from overlapping events**
> **fake jets due to pileup.**

- τ jet
- b jet (tag)

- Correct energy scale from low E_T to very high E_T
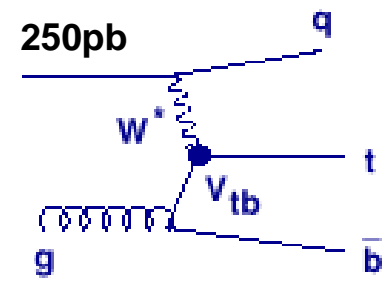**- Better resolution for Jet/MET**

E_T range

20GeV-2TeV
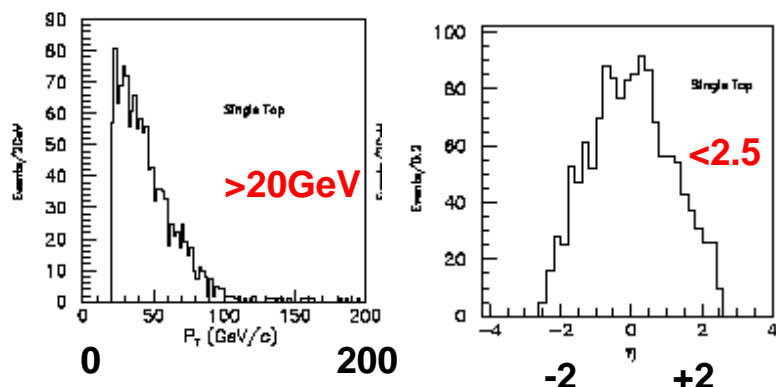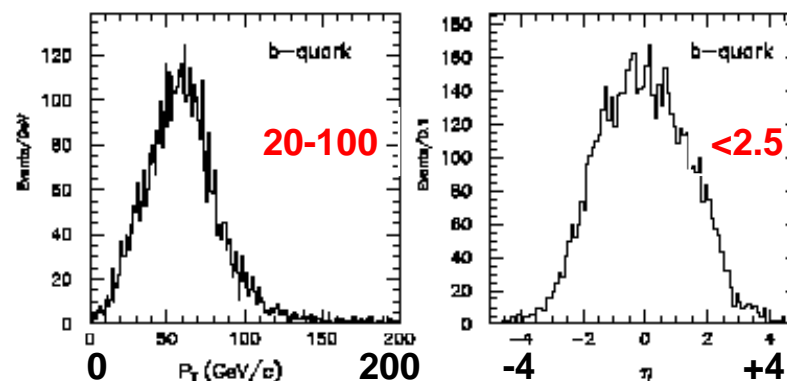

Single Top - Kinematics

250pb

Measurement of
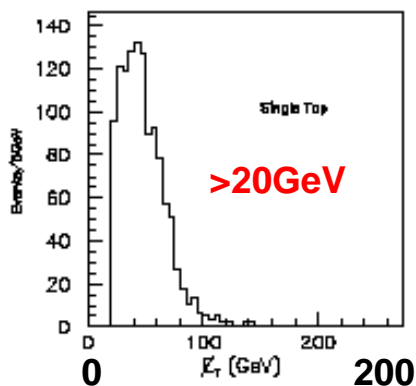**- V_{tb} / top decay properties / background to new physics**

P_T **(lepton)** η **E_T** **(b-quark)** η

>20GeV

<2.5

20-100

<2.5

0   200   -2   +2   0   200   -4   +4

MET   **M_T (l+ν)**   **E_T** **(tagging jet)** η **2.5-4.0**

>20GeV

50-100

>50GeV

0   200   0   200   0   200   -4   +4
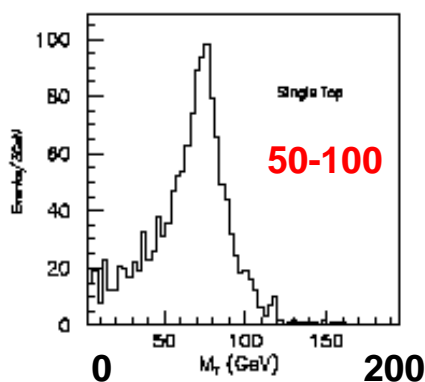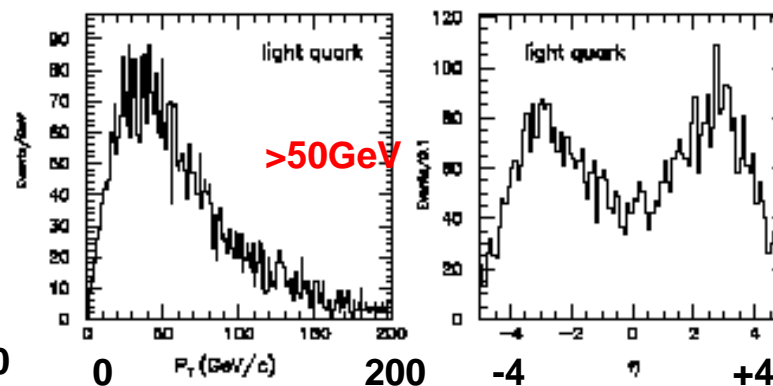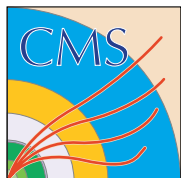
D.Zeppenfeld, R.Kinnunen, A.Nikitenko, E.Richter-Was, Phys.Rev.,D62(2000) pp13009

$gg \to H \to \gamma\gamma$ $M_H < 150$ GeV

$\sim \Gamma_g (\Gamma_\gamma / \Gamma) = Y_\gamma$

$gg \to H \to ZZ \to 4lept$ $M_H > 120$ GeV

$\sim \Gamma_g (\Gamma_Z / \Gamma) = Y_Z$

$gg \to H \to WW \to 2lept$ $M_H > 120$ GeV

$\sim \Gamma_g (\Gamma_W / \Gamma) = Y_W$

$qq \to qqH, H \to \gamma\gamma$ $M_H < 150$ GeV

$\sim \Gamma_W (\Gamma_\gamma / \Gamma) = X_\gamma$

$qq \to qqH, H \to \tau\tau$ $100 < M_H < 150$ GeV

$\sim \Gamma_W (\Gamma_\tau / \Gamma) = X_\tau$

$qq \to qqH, H \to WW \to 2lept$ $M_H > 120$ GeV

$\sim \Gamma_W (\Gamma_W / \Gamma) = X_W$

Accuracy expected with 200 fb^{-1} of data with ATLAS+CMS detectors at LHC

accuracy of Higgs boson width and partial H→WW width

- $\Gamma_W(1-\varepsilon)$
- $\Gamma(1-\varepsilon)^2$
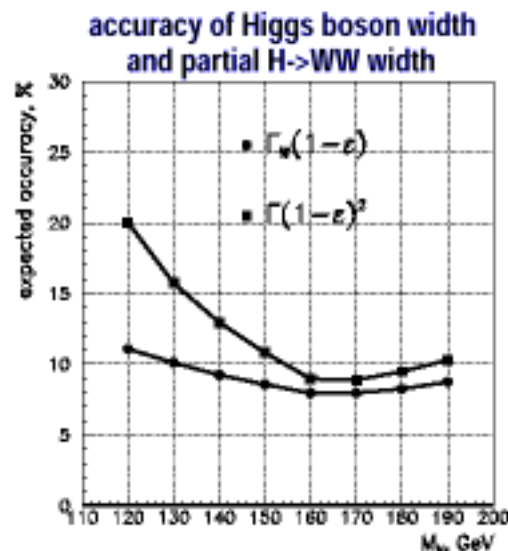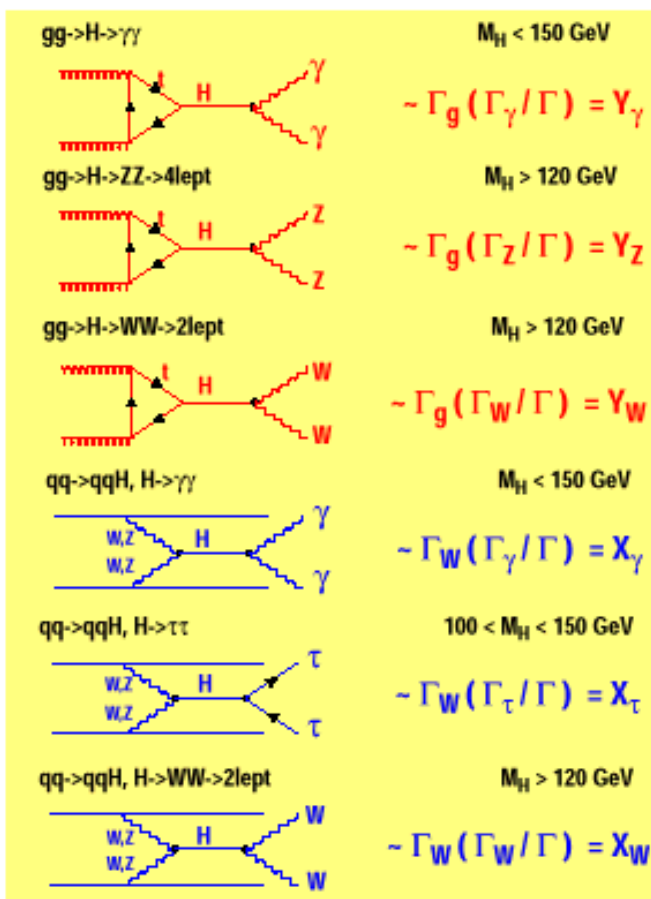
❏ measure Hγγ, Hττ, Hgg couplings at 10 % level
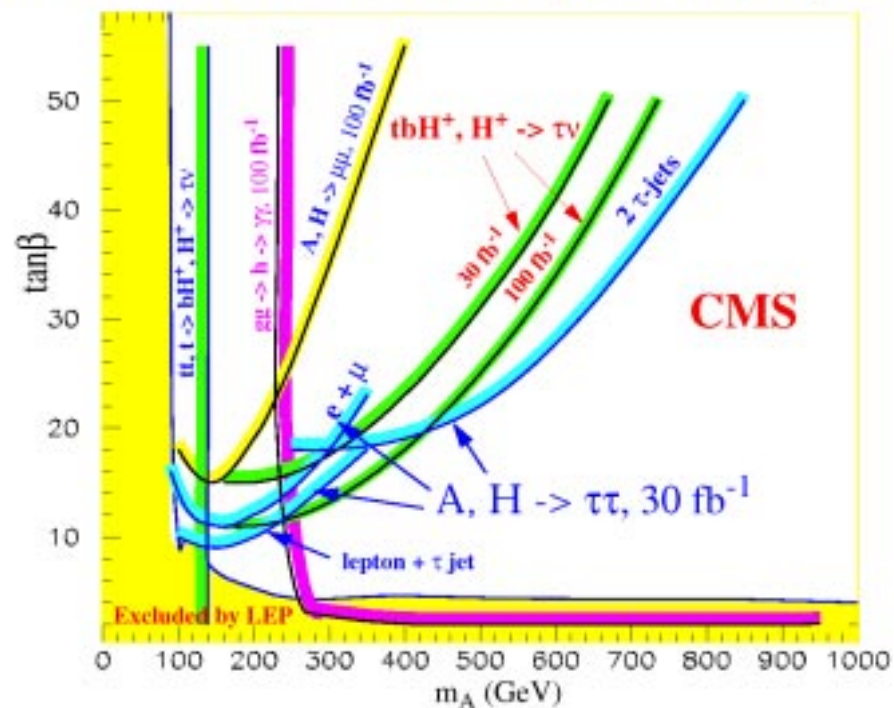
❏ hWW coupling ($|\sin(\beta-\alpha)|$) can be measured at 5% level

Although σ(VBF)~σ(GF)/3, VBF process may play a big role in measurement of higgs properties in addition to discovery potential.

τ jet

Branching ratios for H⁺
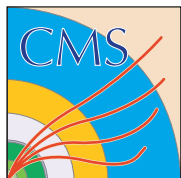

tanβ = 30 (upper plot)

tb, τν, H⁺, No stop mixing

tanβ = 3 (lower plot)

tb, τν, H⁺, No stop mixing

M(H⁺)   200   500   1000
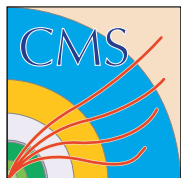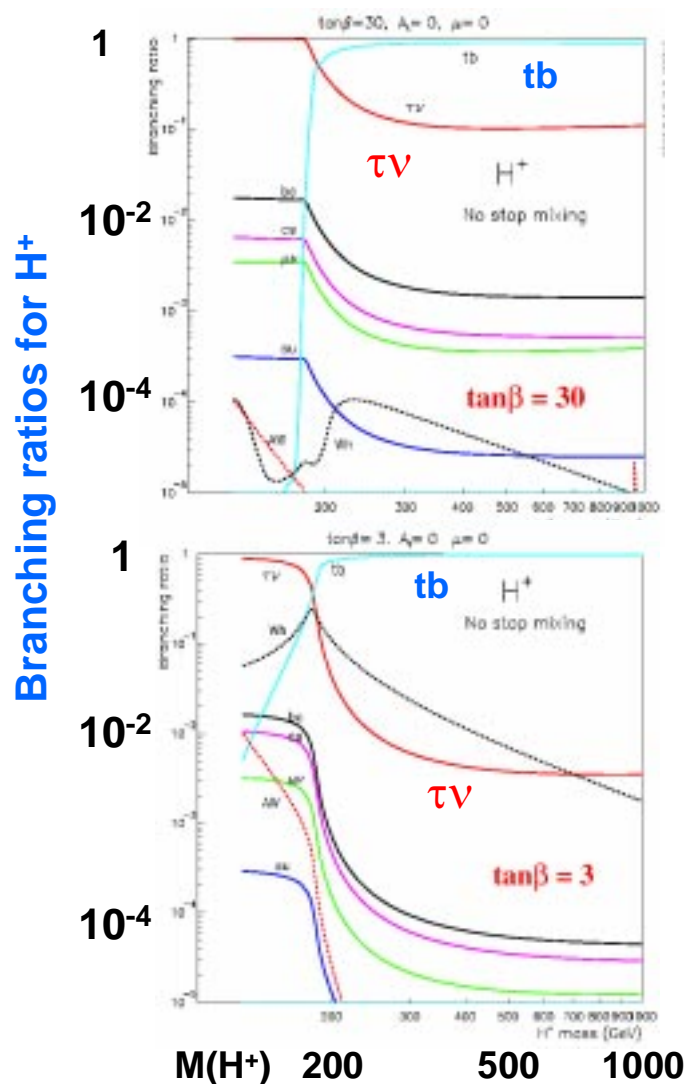
5σ contours for the main discovery channels at high tanβ

tbH⁺, H⁺ -> τν

A, H -> μμ, 100 fb⁻¹

2 τ-jets

30 fb⁻¹   100 fb⁻¹

CMS

e + μ

A, H -> ττ, 30 fb⁻¹

lepton + τ jet

Excluded by LEP

m_A (GeV)

1 prong τ decay (τ jet)

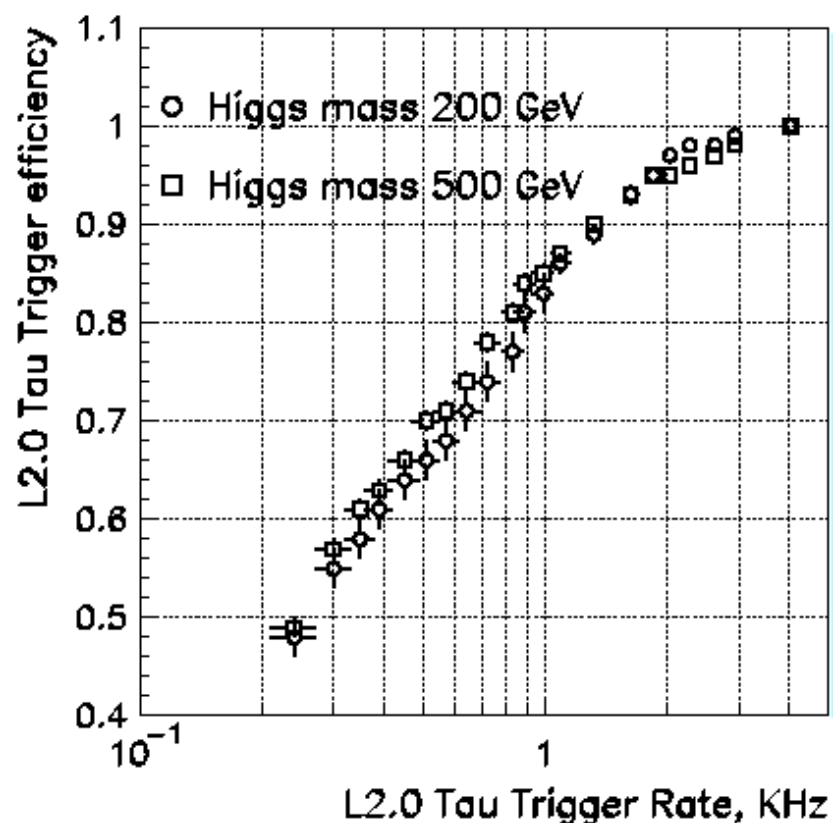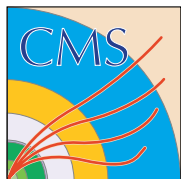|	
$\tau^+ -> \pi^+ \nu$	12.5%
$\tau^+ -> \rho^+ \nu -> \pi^+ \pi^0 \nu$	26%
$\tau^+ -> a_1 \nu -> \pi^+ \pi^0 \pi^0 \nu$	7.5%

τ jets

tau jet:
　　narrow (one prong) jet

L1/L2:
　　use only calorimeter
　　　　L1: 0.087x0.087
　　　　L2: individual crystal

L2.0 Tau trigger

1. reconstruct a Jet*

2. calculate e.m. isolation :

　$P_{isol} = E_t^{ecal}(R < 0.4) - E_t^{ecal}(R < 0.13)$
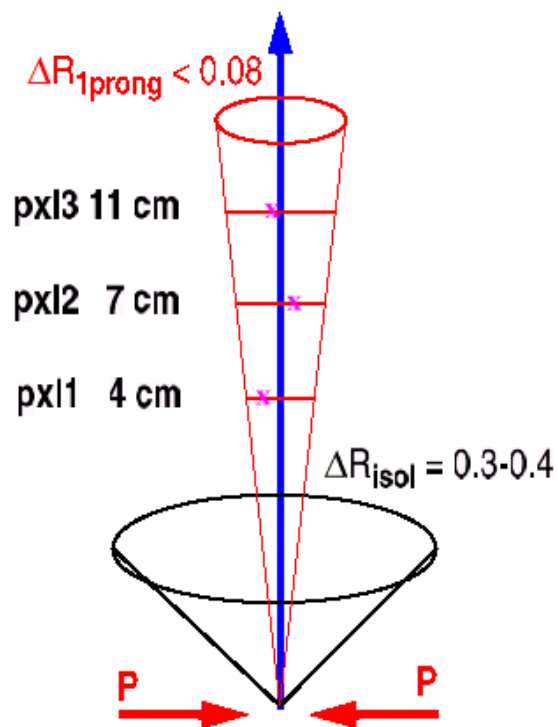
3. accept event if $P_{isol} < P_{cut}$

gg->bbA, A->2τ->h⁺ + h⁻ + X

tau jets at L3

Jet direction given by L2.0 Tau object

$\Delta R_{1prong} < 0.08$

pxl3 11 cm

pxl2 7 cm

pxl1 4 cm

$\Delta R_{isol} = 0.3\text{-}0.4$

P → ← P

1. **Tracks are reconstructed with 3 pixel layers only within a cone given by L2.0 jet axis.**

2. **Isolation cuts: tracks in a big cone (0.3-0.4) vs. a small cone (~0,1), PT(tr)>1-2GeV**

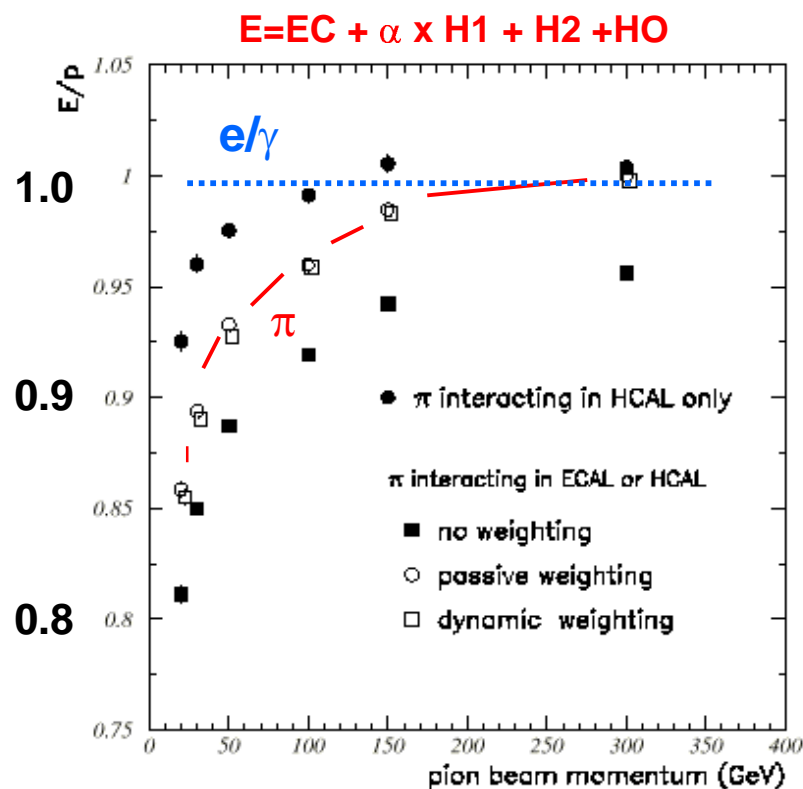**gg->bbA(500GeV)**

Signal efficiency vs. QCD bkg. efficiency
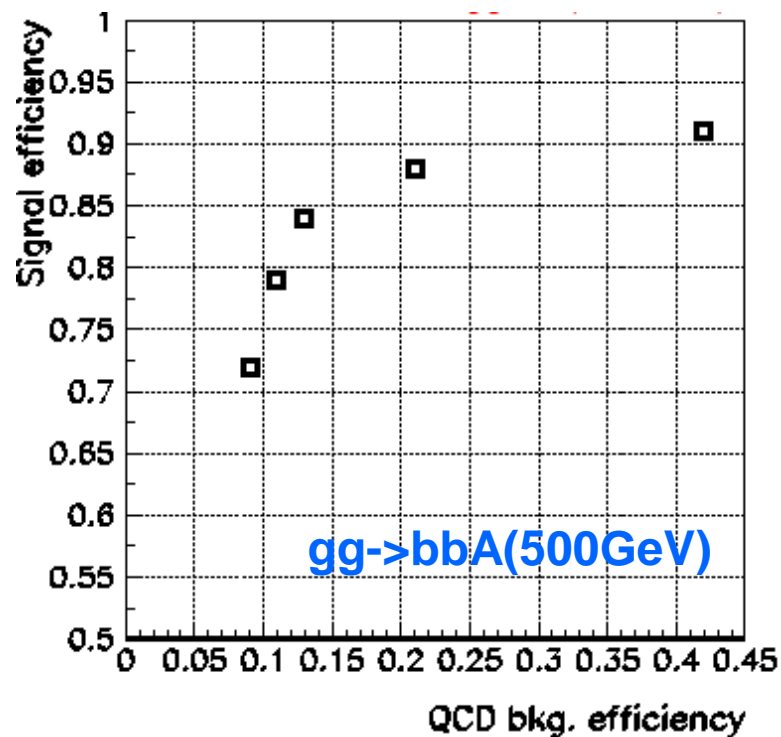
(Nikitenko & Kotlinski : cms116 analysis)
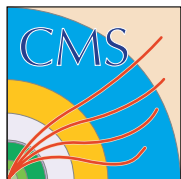
Pion Response: Linearity

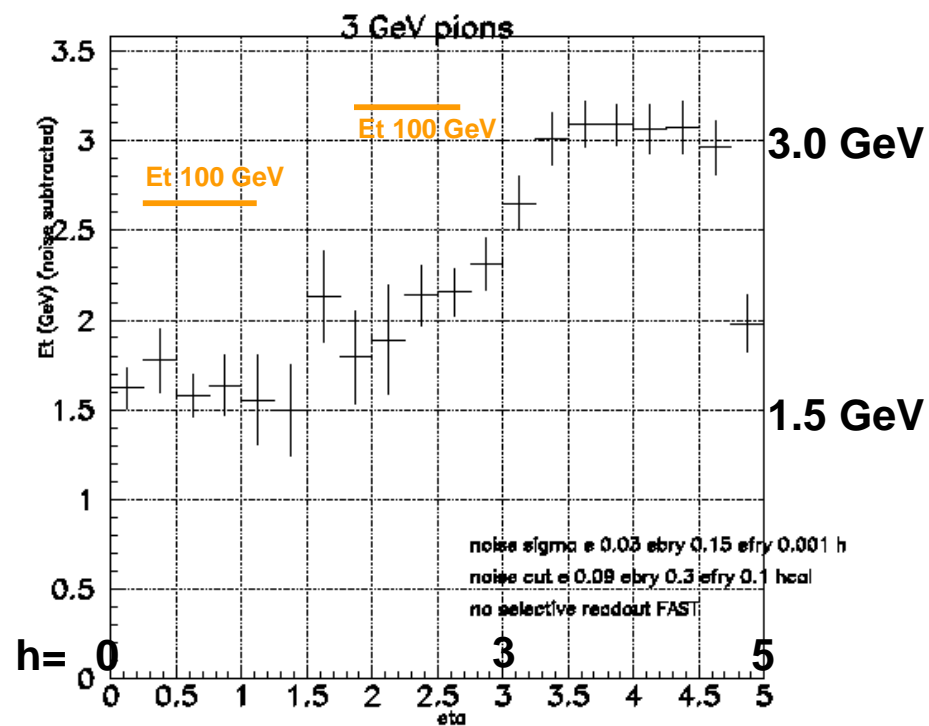**ECAHL+HCAL: Non compensating calorimeter**

96'H2 Teast Beam Data

$E=EC + \alpha \times H1 + H2 + HO$

CMS Simulation

ET=3 GeV pion in 0<|η|<5

e/γ

π

• π interacting in HCAL only

π interacting in ECAL or HCAL

■ no weighting

○ passive weighting

□ dynamic weighting

pion beam momentum (GeV)

P= 0   200   400GeV

3 GeV pions

3.0 GeV

1.5 GeV

noise sigma e 0.03 ebry 0.15 efry 0.001 h
noise cut e 0.09 ebry 0.3 efry 0.1 hcal
no selective readout FAST

h= 0   3   5

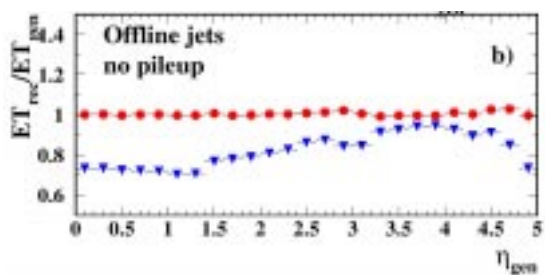E= 3   7   30   82   227 GeV

Jet Response and Correction #1

(S.Arcelli)

Et-eta dependent correction for QCD jets

No pileup

$$Et(corr) = a + b \times E_T(rec) + c \times E_T(rec)^2$$

With pileup
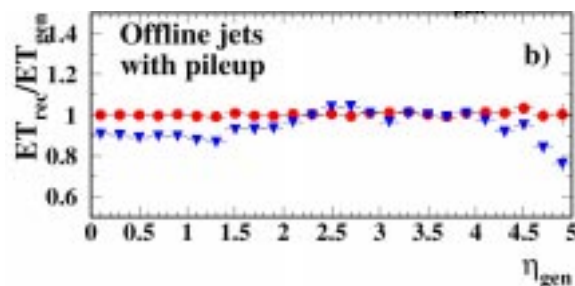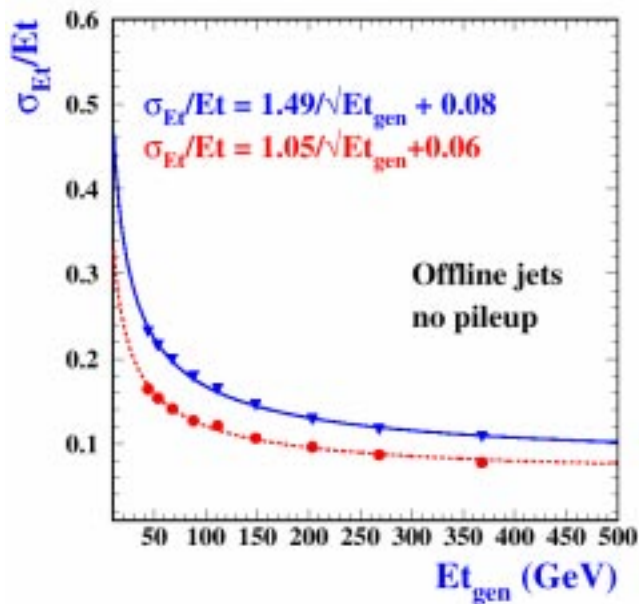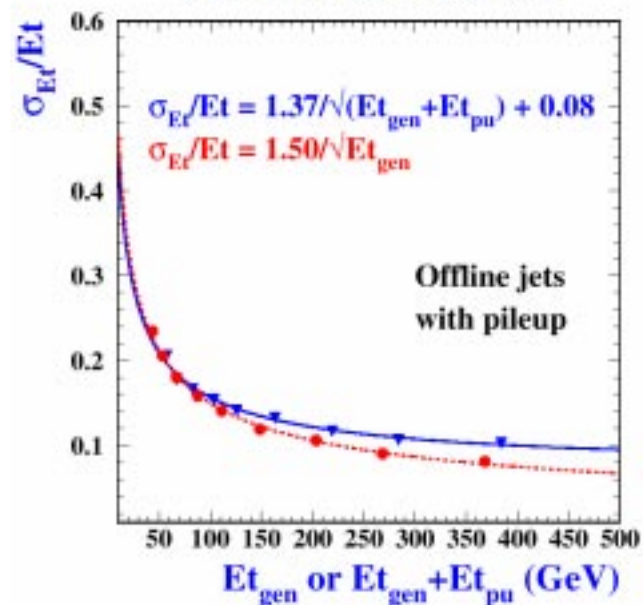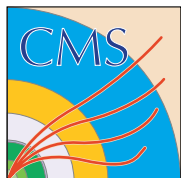
Dijet Mass Resolution

No pileup

With pileup

W(jj)   Top(jjj)

Before correction

M(bb) in ttH

ORCA4:
resolution1 = 14.0%

W mass $m_{fit} = 80.5$ GeV $\sigma_{fit} = 15\%$

15%

q and q' assigned to the same jet ~ 0.7%

top mass $m_{fit} = 165.6$ GeV $\sigma_{fit} = 21\%$

21%

After correction

Jet energy correction

without: **19%**

with: **14%**

CMSJET   **15%**

W mass $m_{fit} = 85.2$ GeV $\sigma_{fit} = 16\%$

16%

top mass $m_{fit} = 178.1$ GeV $\sigma_{fit} = 22\%$

22%

(S.Arcelli & V.Drollinger)   (R.Kinunnen)

MET

Energy scales for MET

QCD 2j event
p_t bin 80-120 GeV
high lumi

E_t in tower, GeV

14
12
10
8
6
4
2
0

0

calo tower in η

η

-5.0   π

φ

0

0

Jet energy scale

out of cone energy scales :

- physics (FSR)
- 4T field
- pile up
- underying event

Out of cone corr. uses weights for jet(30GeV) corr.

min.bias corrections

$(E_t^{em}+E_t^{hd})/E_t^{MC}$

E_t reco / E_t inp

1.1
1
0.9
0.8
0.7
0.6
0.5

5   10   15   20   25

η tower number

$C=E_t^{rec.jet}(r<0.5)/E_t^{rec.jet}(r<0.5)$
for $E_t^{rec.jet}$ = 30 GeV

corr. for jet E_t^{MC}=30 GeV

1.1
1
0.9
0.8
0.7
0.6
0.5

Silvia corrections for 30 GeV jets

0   0.5   1   1.5   2   2.5   3
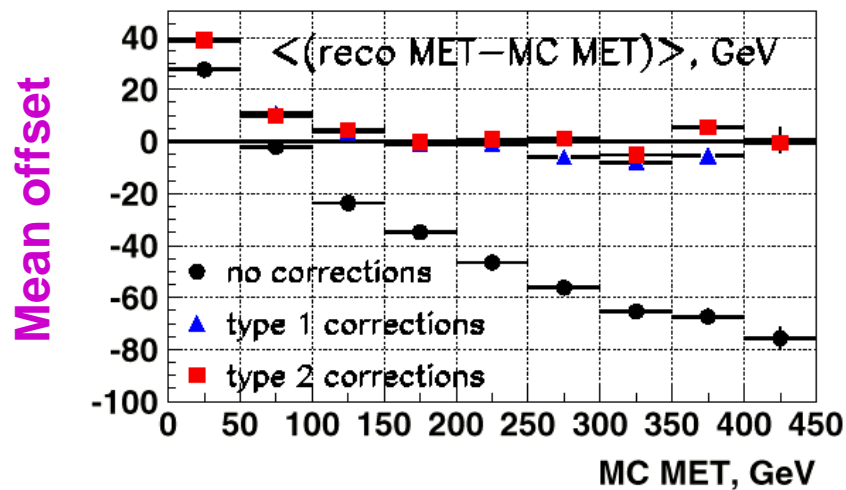
η jet

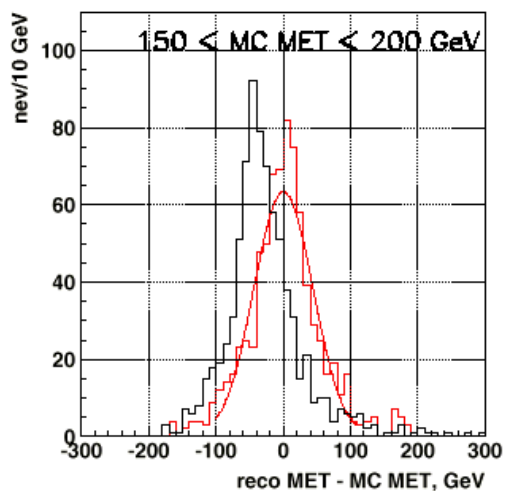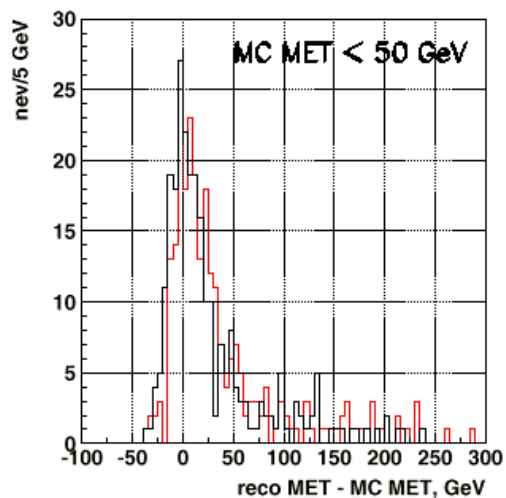**Corrections**
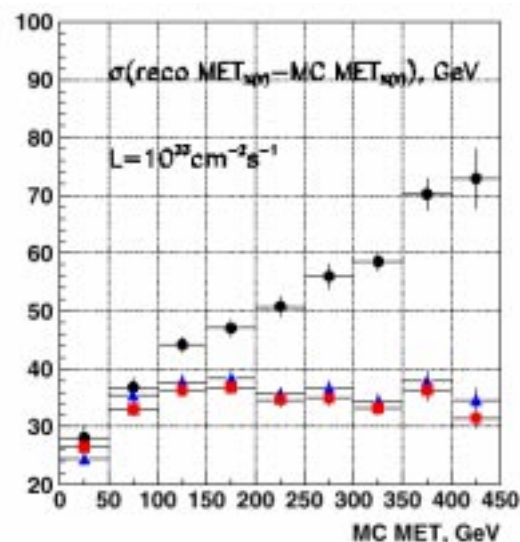**Type 1:   Jet corr.**
Type 2:   Jet corr. + out of cone corr.
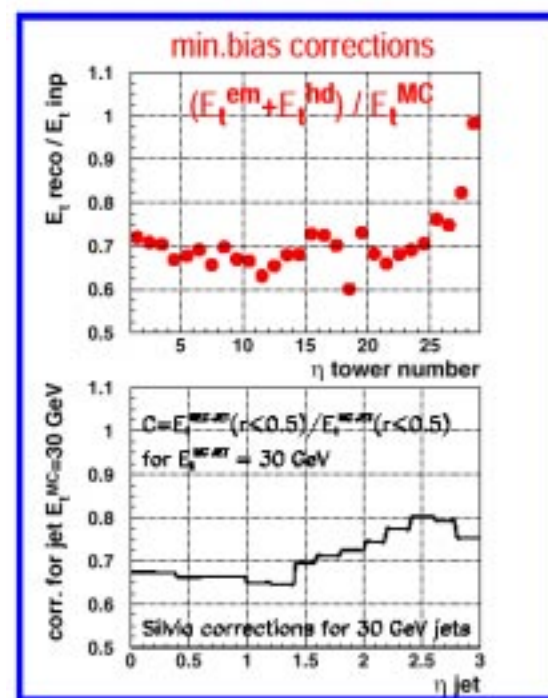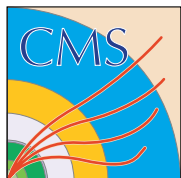
Corrected MET for mSUGURA Jets+MET at low lumi
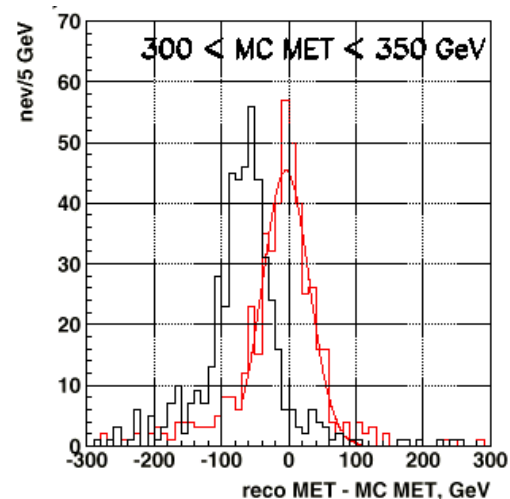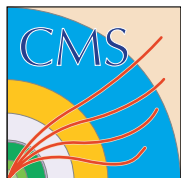
Higgs mass in bbA, A→2τ→2j

(A.Nikitenko)

before correction
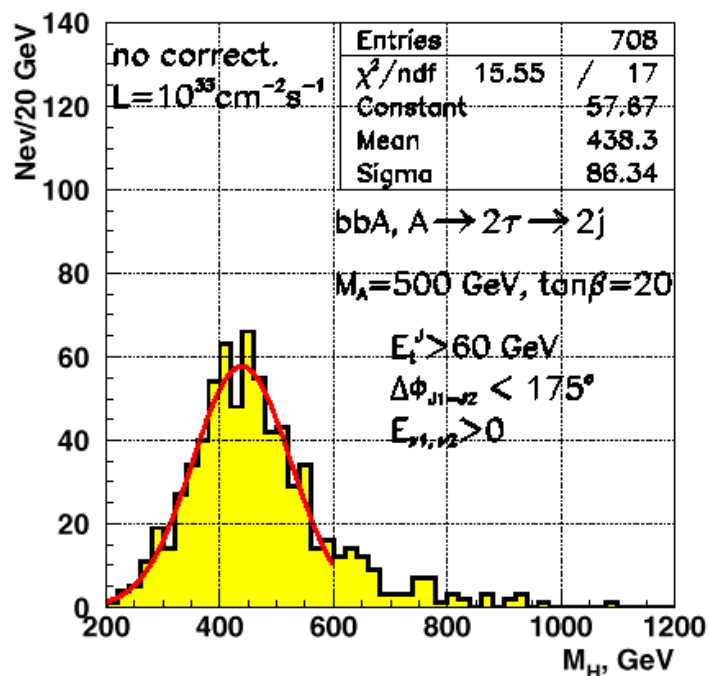
after correction
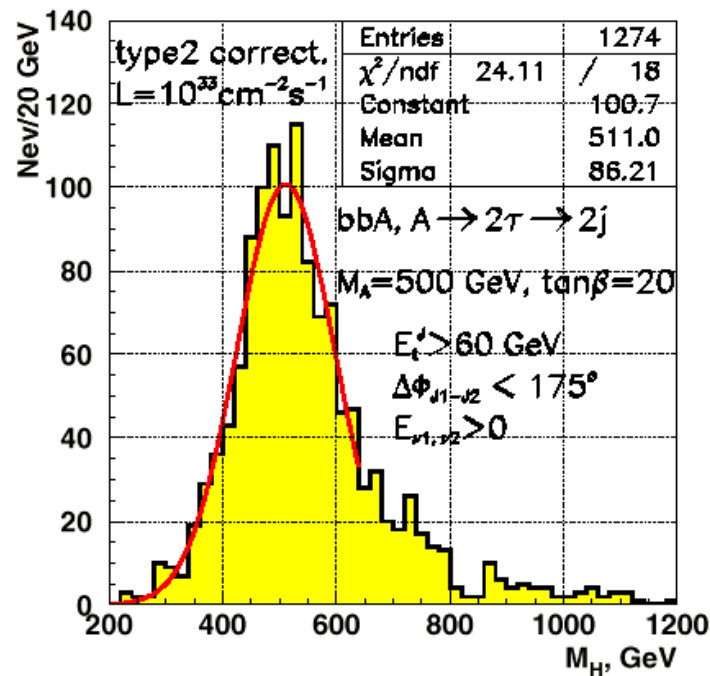
bbA, A->2τ->2j	no corrections	type1 corrections	type2 corrections	CMSJET
<M_H>	438.3 GeV	500.3 GeV	511.0 GeV	500.0 GeV
σ / <M_H>	19.7 %	18.9 %	16.8 %	13.4 %
ε reco (corr.) / (no corr)	1	1.53	1.80	
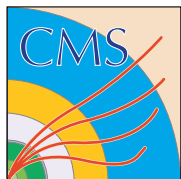
Jet correction method #2

Jet Corr. #1

α **x (EC+HC)**

- corr. for jet energy scale
- α depends on jet(Et,η)

Jet Corr. #2

α **x EC +** β **x H1 +** γ **x H2**

- optimize jet resolution
  (and jet energy scale)
- α, β, γ depends on jet(Et,η)

Optimized weights by #2
**0.0<η<0.4**
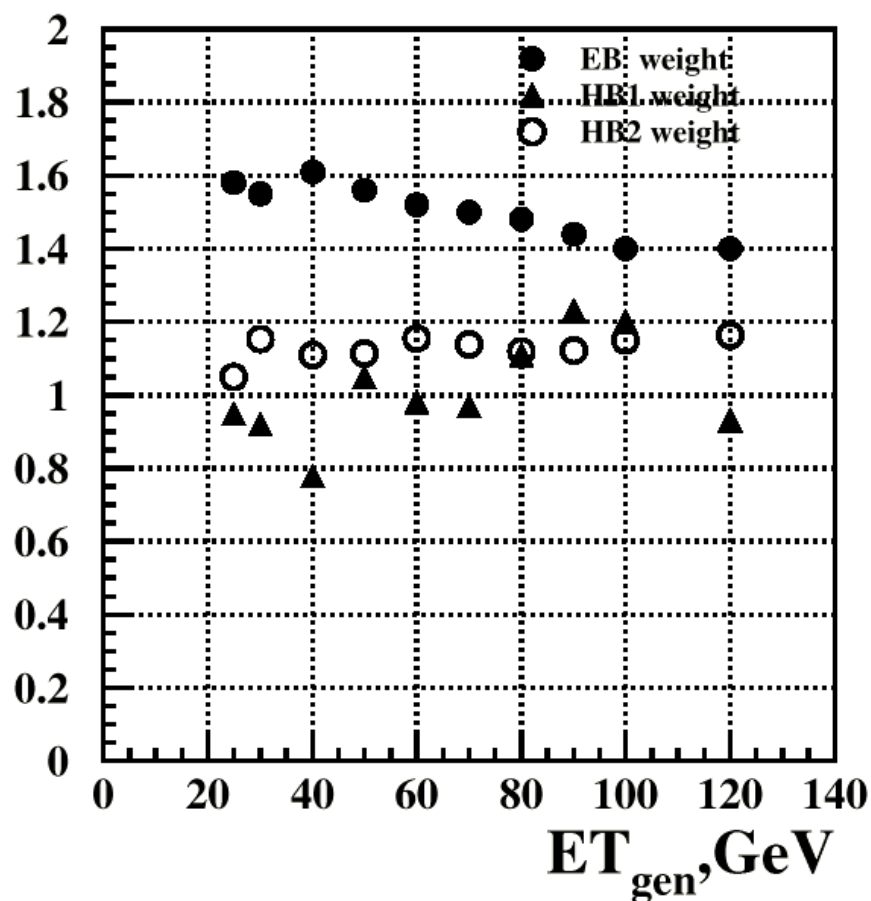
(A.Oulianov)
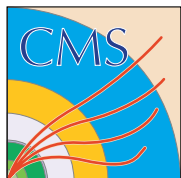
Jet Correction method #2

Table 1: Optimum weights and energy resolutions for ET=80 GeV jets

eta range	eb	hb1	hb2	ee	he1	he2	RESOLUTION CMSIM120 weights + energy corrections	RESOLUTION optimum weights
0.0 - 0.4	1.48	1.12	1.12				0.143	0.136
0.4 - 0.8	1.49	0.95	1.19				0.141	0.134
0.8 - 1.1	1.49	1.08	1.19				0.144	0.137
1.25-1.45	1.47	0.98	1.40	1.89	1.26	1.54	0.136	0.133
1.7 - 2.0				1.44	1.04	1.15	0.134	0.128
2.0 - 2.4				1.32	1.03	1.15	0.123	0.120

Table 3: Optimum weights and energy resolutions for ET=120 GeV jets

eta range	eb	hb1	hb2	ee	he1	he2	RESOLUTION CMSIM120 weights + energy corrections	RESOLUTION optimum weights
0.0 - 0.4	1.40	0.93	1.16				0.124	0.119
0.4 - 0.8	1.41	1.13	1.13				0.132	0.126
0.8 - 1.1	1.40	1.16	1.16				0.125	0.121
1.25-1.45	1.44	0.82	1.37	1.85	0.55	1.73	0.125	0.119
1.7 - 2.0				1.37	0.91	1.14	0.122	0.116
2.0 - 2.4				1.29	0.70	1.17	0.117	0.113
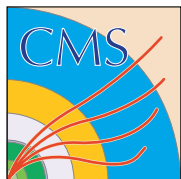
Correction method #3a
(single pion)

(V.Genchev)

Method #3

$$E_{nl}^{rec} = \sum_{i=1,4} f_i(\vec{A}, E_i)E_i,$$

Method #1

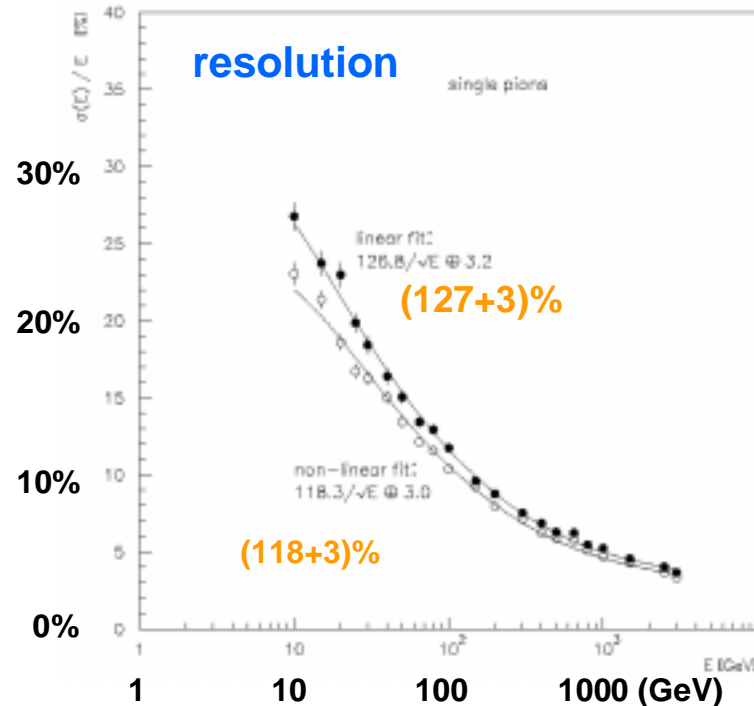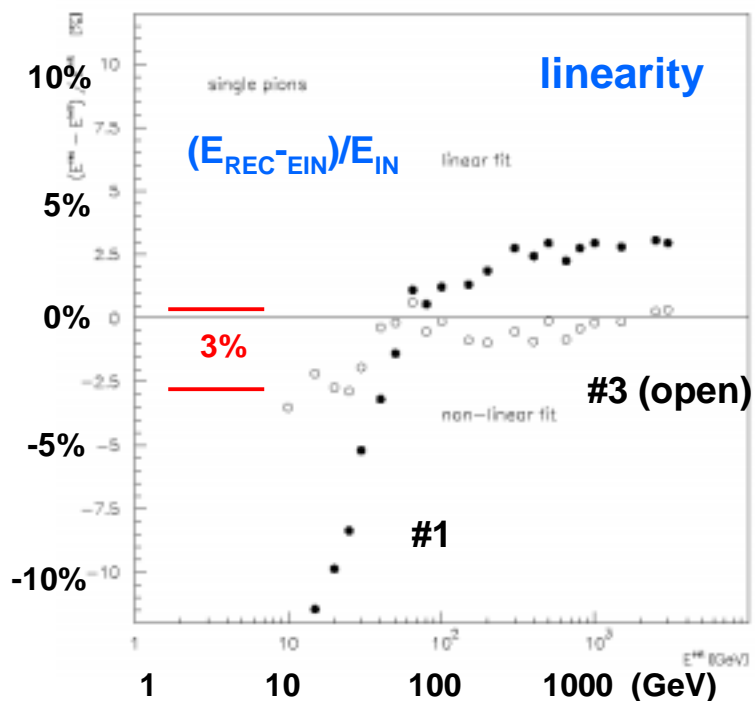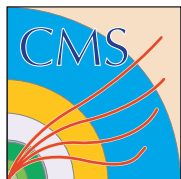$$E^{rec} = \sum_{i=1,4} C_i E_i,$$

i : longitudinal segmenation

Minimize $\chi^2 = 1/(M-N+1) \sum_{j=1,M} W_j(E_j^{in} - E_{nl,j}^{rec})^2,$ with cmsim.

linearity

single pions

$(E_{REC}-E_{IN})/E_{IN}$ linear fit

3%

non-linear fit

#3 (open)

#1

1   10   100   1000 (GeV)

resolution

single pions

linear fit:
126.8/√E ⊕ 3.2

(127+3)%

non-linear fit:
118.3/√E ⊕ 3.0

(118+3)%

1   10   100   1000 (GeV)

Linearity is restored to 3% in 10-1000GeV for single pion!

$$E = 1/e_E (e/\pi)_E R_E + 1/e_H (e/\pi)_H R_H$$

$$F_o = E_e / E \sim 0.11[\ln(E)]$$

$$e/\pi = e/h/[1+(e/h-1)F_o]$$

$(e/h)_{HCAL} \sim 1.39$ (NIM paper)

To find e/h for ECAL, measure e/pi at different energies for showers where there is a substantial energy (> 30% of the beam energy) in ECAL.

$(e/h)_{ECAL} \sim 1.60$

Linearity is restored to a few %. The resolution is Gaussian to a high level of accuracy with ~ NO constant term and a 120% stochastic coefficient

e/h for ECAL and HCAL - Linearity

linearity

reco

<E(GeV)>

beam

0   100   200   300 (GeV)

Ebeam(GeV)

d2/E = (sample rms)/(sample mean)
for e/h of HCAL and ECAL

resolution

σ/E

σ(E)/<E>

curve is dE/E=110%/sqrt(E)

10   100   300 (GeV)

Ebeam(GeV)

Next: identify em cluster and had cluster in jet using transverse shower shape (in crystals) and reco-ed tracks and apply this to had cluster.

Correction Method #3b-j (single pion)

(J.Freeman)

$$E = 1/e_E (e/\pi)_E R_E + 1/e_H (e/\pi)_H R_H$$
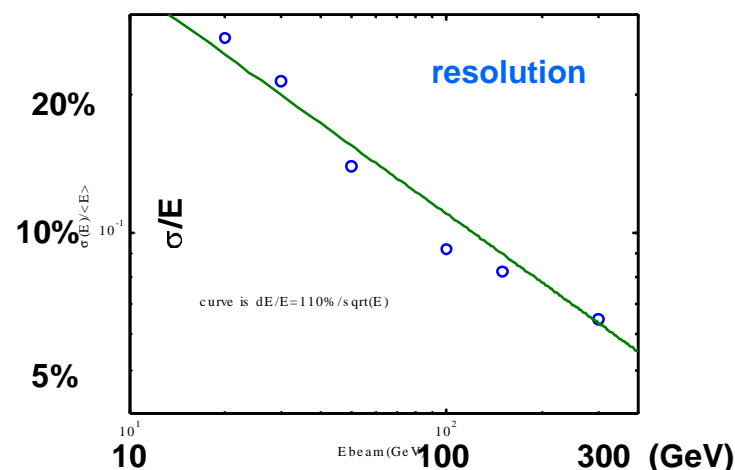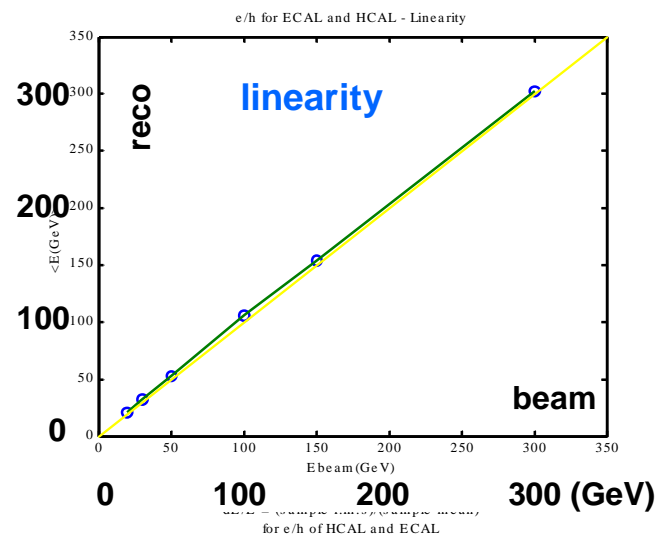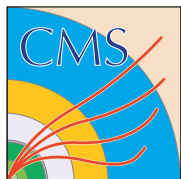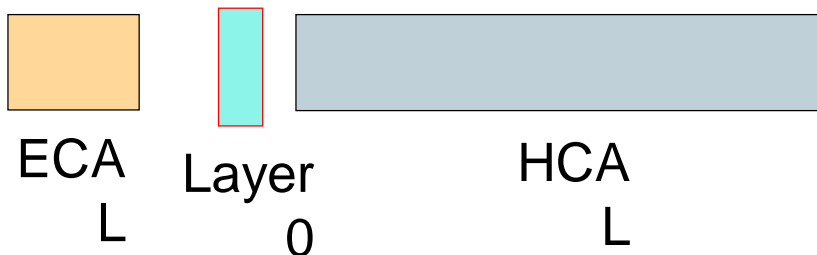
$$F_o = E_e / E \sim 0.11[\ln(E)]$$
$$e/\pi = e/h / [1 + (e/h - 1)F_o]$$

$(e/h)_{HCAL} \sim 1.39$ **(NIM paper)**

To find e/h for ECAL, measure e/pi at different energies for showers where there is a substantial energy (> 30% of the beam energy) in ECAL.
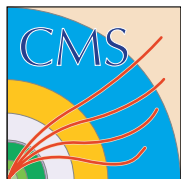
$(e/h)_{ECAL} \sim 1.60$

Same as #3b, except-

(R1)

$R_E = 4*(L0/HC)*(EC+HC)$

with constraint: RE<(EC+HC)

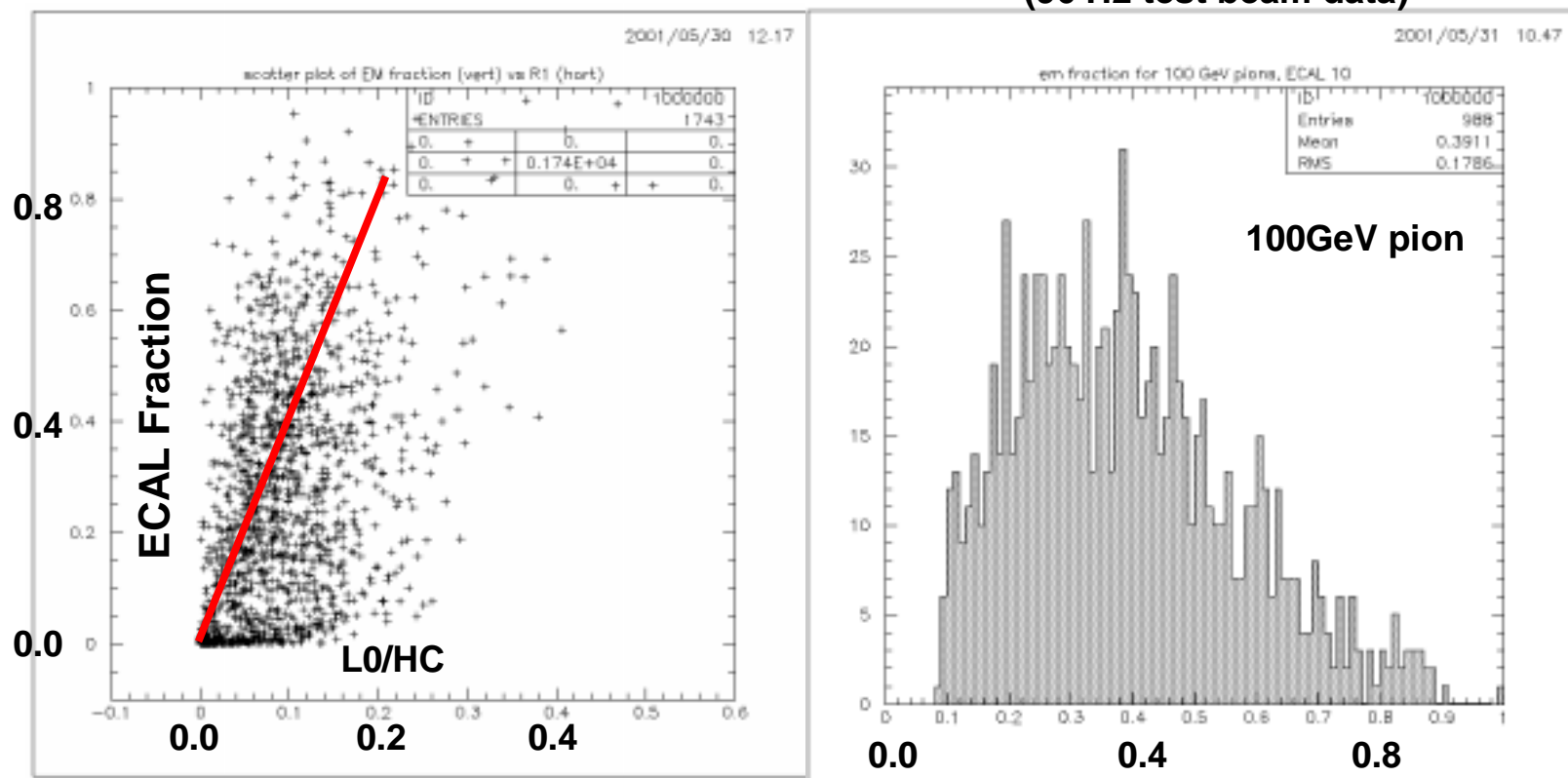**(average)**

$R_E = 0.4*(EC+HC)$

ECAL   Layer 0   HCAL

ECAL fraction vs. L0

(96'H2 test beam data)

scatter plot of EM fraction (vert) vs R1 (hort)

ECAL Fraction

L0/HC

em fraction for 100 GeV pions, ECAL 10

100GeV pion

Week correlation

Red line for

ECAL fraction=4.0*L0/(HC)

ECAL fraction

< EC/(EC+HC) > = 0.3911
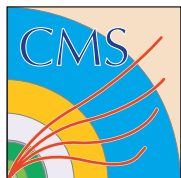
Correction #3b
single pion response

resolution

linearlity

AVE = •

R1 = *

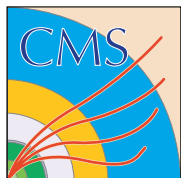Dan = o
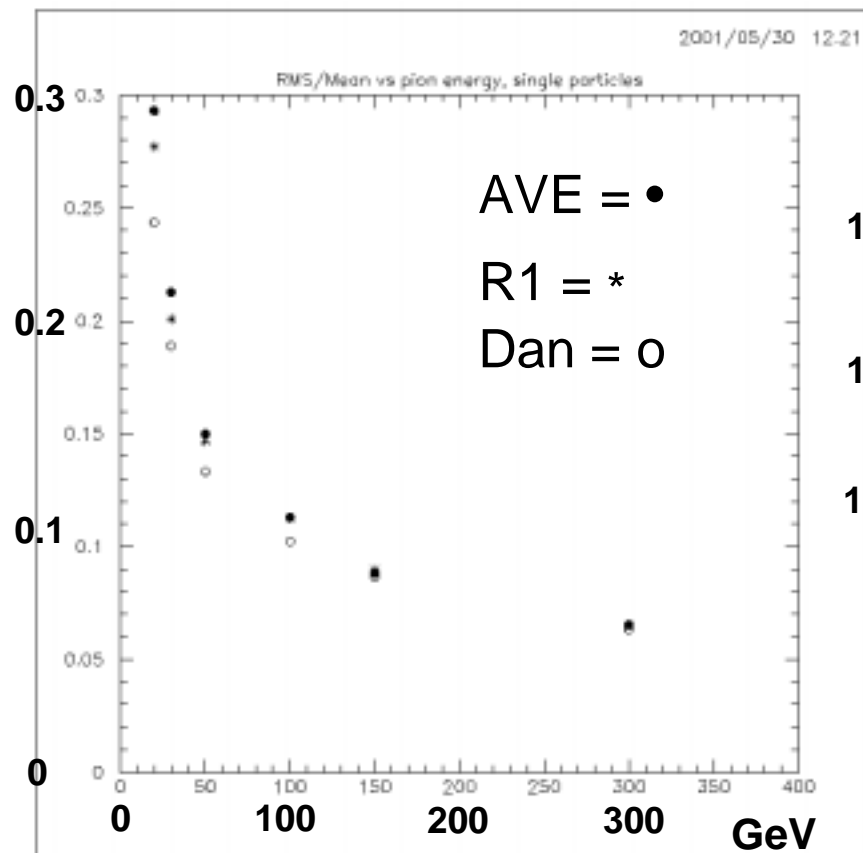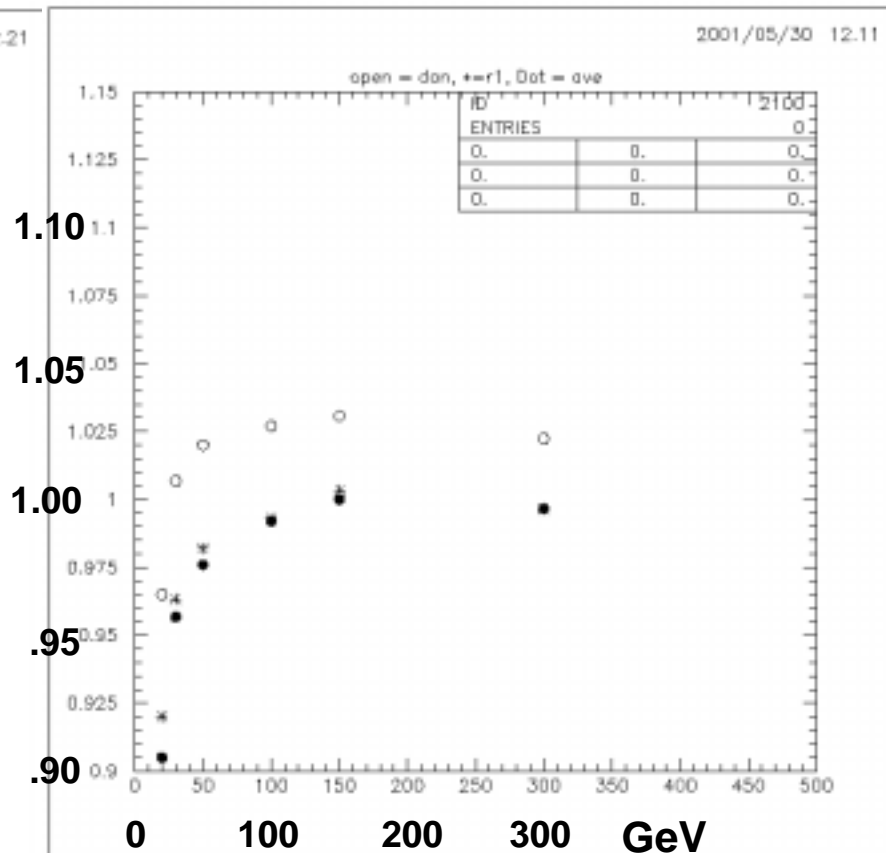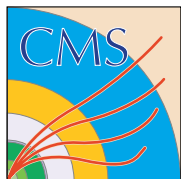
Correction #3b
"jet" = pion + 100GeV γ
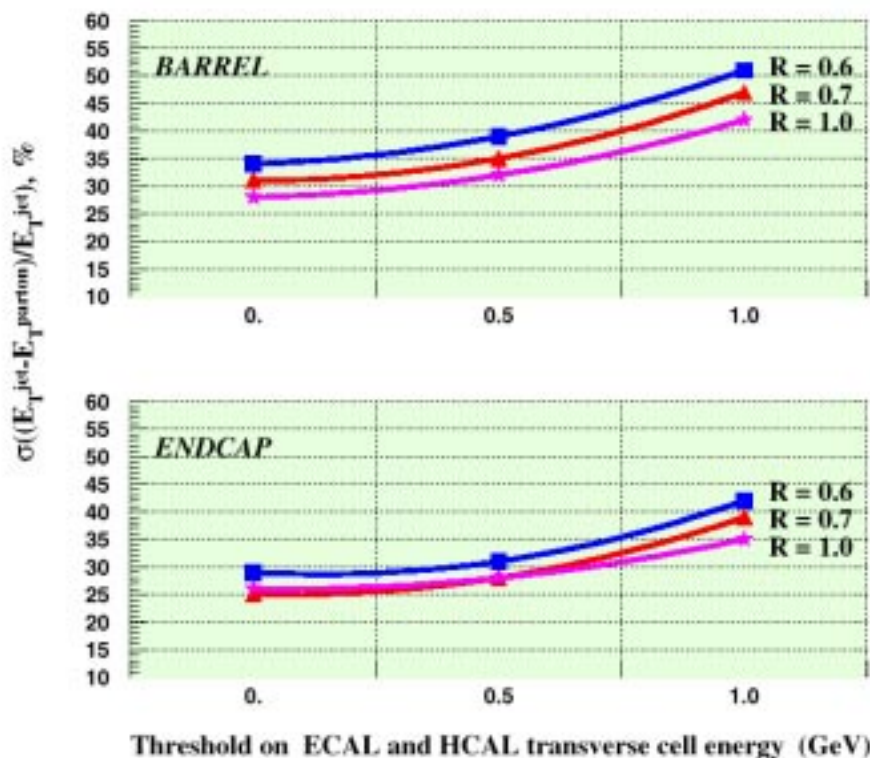
Resolution
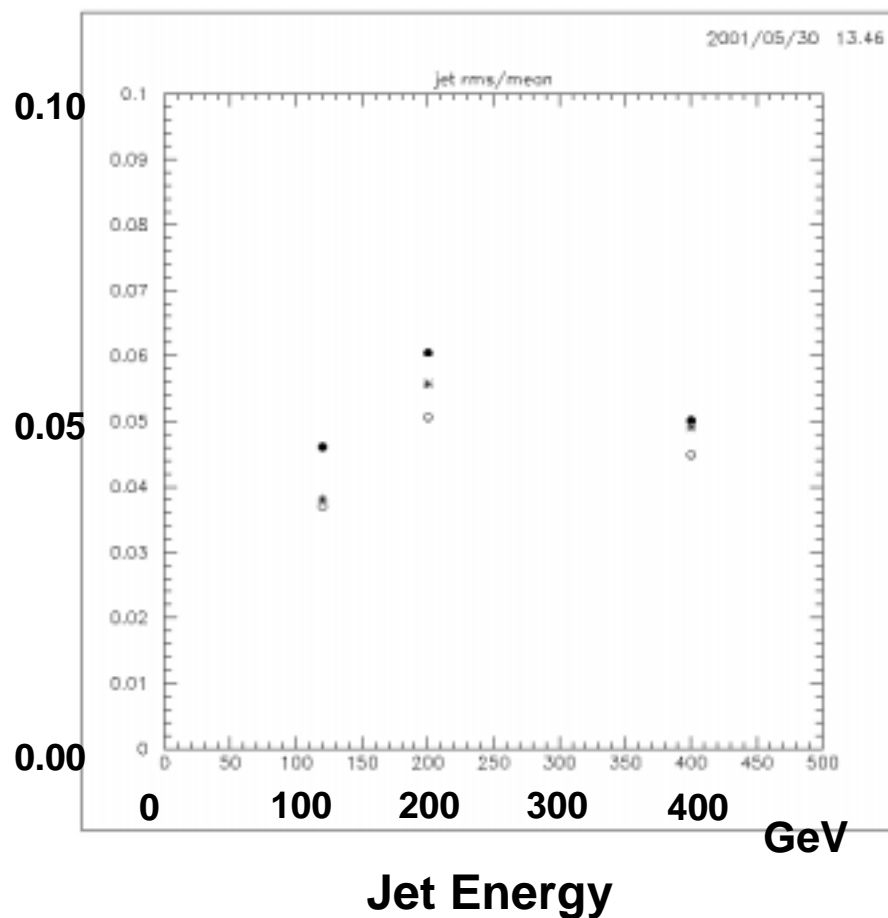
Linearity
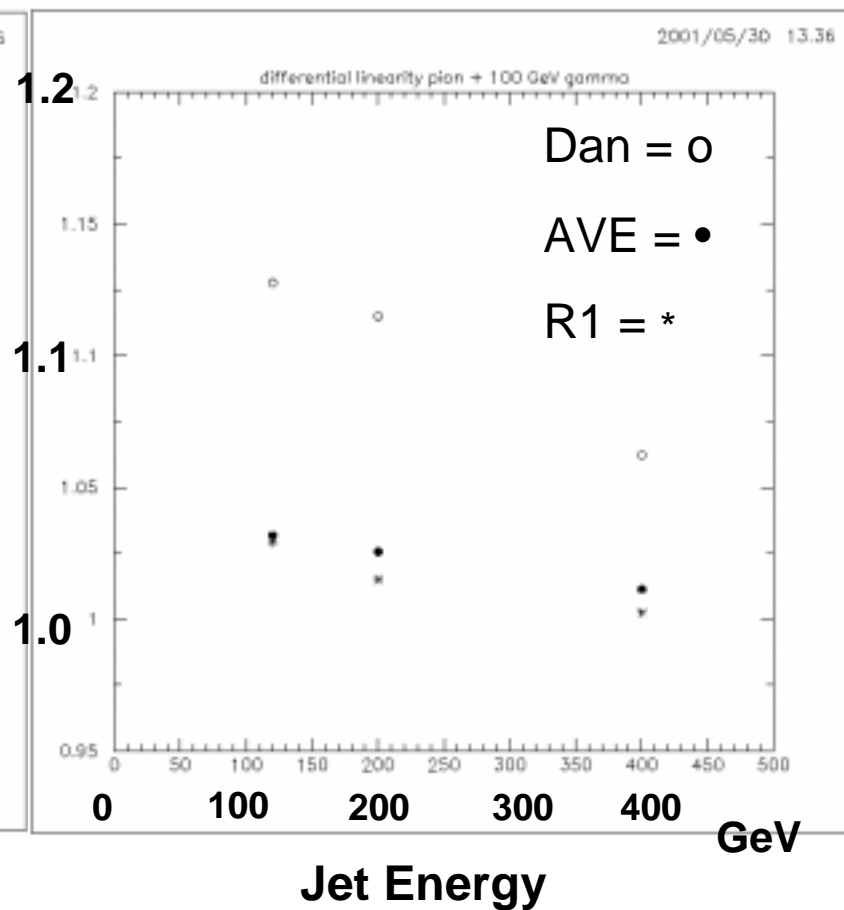
How about real jets?

Effect of Threshold on low E_T jet and MET

20GeV parton jet @ 10E34

MET

(I.Vardanian)
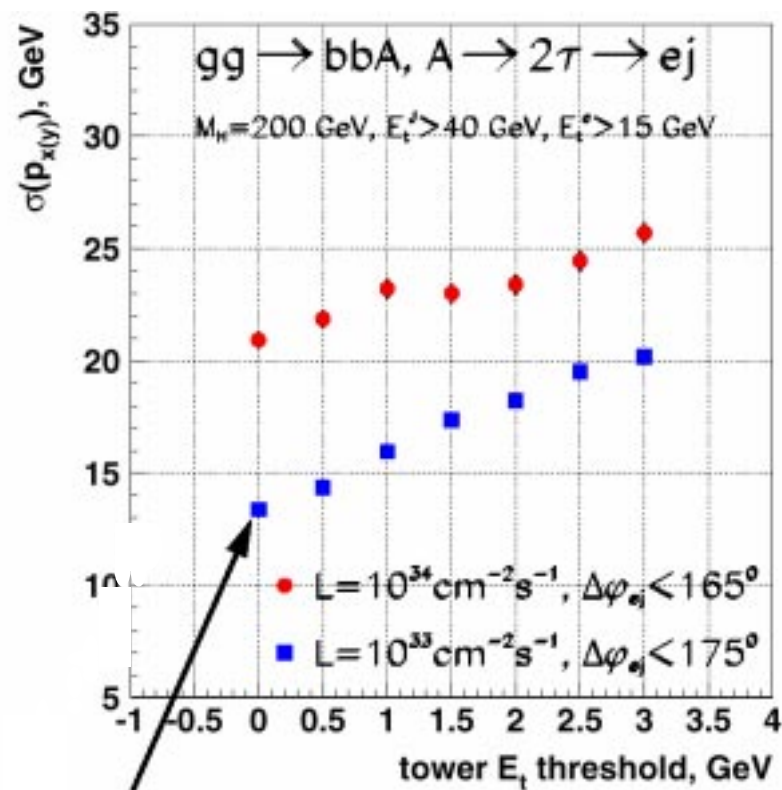
(S.Nikitenko)

Lower threshold is better!

Electronics noise and occupancy define the threshold.

>> aim at **0.5GeV/tower** **@ 10E34**
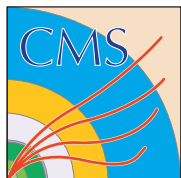
Front end electronics simulation

(S.Abdoullin)

$\sqrt{}$ - shape contributions
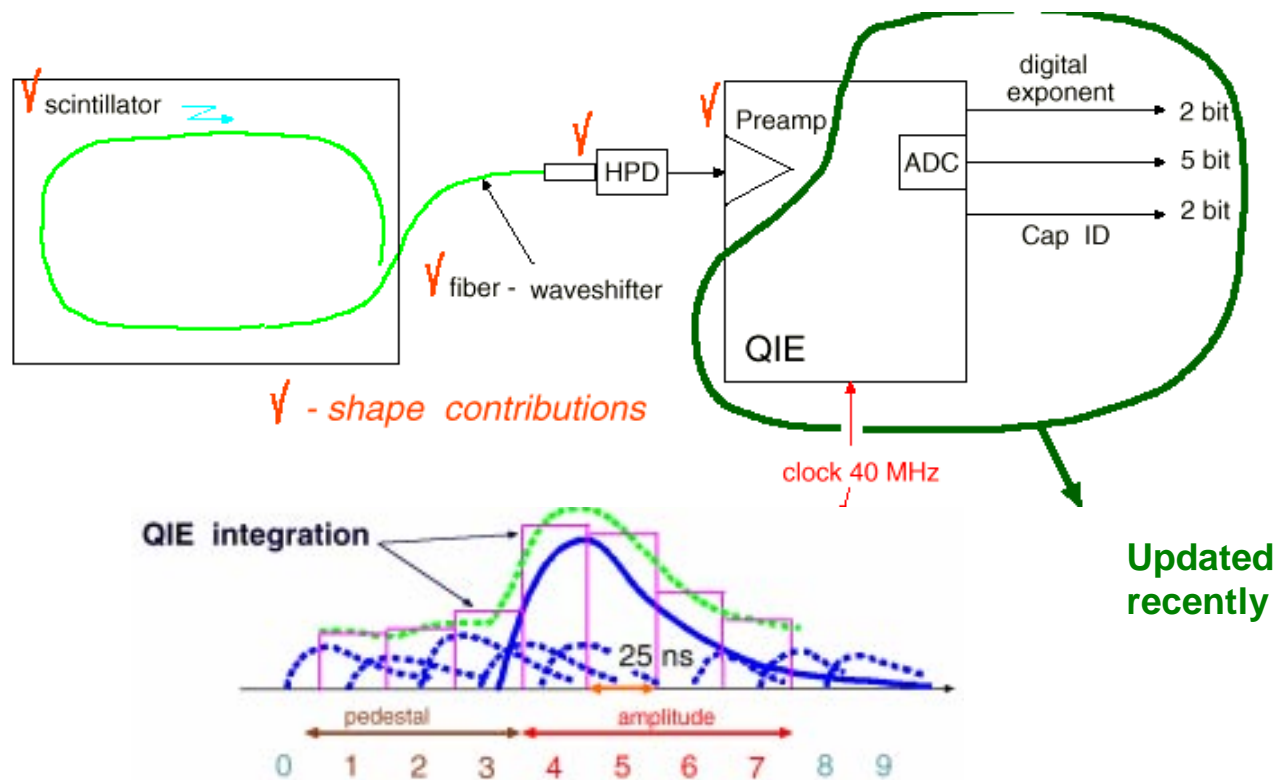
Updated recently

$$E = \Sigma \, (\text{Signal buckets})_i - \Sigma(\text{pre buckets})_j/n$$

Electronics noise 200MeV/25nsec/ch $\rightarrow$ 500MeV/(3+3) buckets/ch

$\rightarrow$Looking for better method for energy calculation
& bunch crossing ID.

Algorithm for L1 through Offline (1)

L1 – calorimeter only (coarse segmentation)

- **Resolution improvement**
  - Equalize calorimeter response with simple correction
    - **a x (EC+HC),   a depends on jet(ET,h)**
    - **a x EC + b x HC,   a,b depends on jet(ET,h)**
- **Fake Jets/Pileup jets rejection**
  - Threshold cut on a central tower in jets (seed cut)

L2 – calorimeter only (fine segmentation)

- **Resolution improvement**
  - Better energy extraction from ADC counts
  - Em/had cluster separation using transverse shower shape in crystals
- **Fake jet/Pileup jet rejection**
  - Use of transverse shower shape
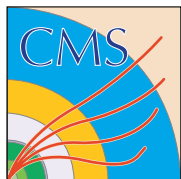
Algorithm for L1 through Offline (2)

L3 – calorimeter plus pixel

- **Resolution improvement**
  - Pileup energy subtraction
    - **Estimation of energy flow from pileup events using pixel hits/tracks.**
- **Fake jets/Pileup jets rejection**
    - **Vertex information and jet pointing using pixel hits/tracks.**
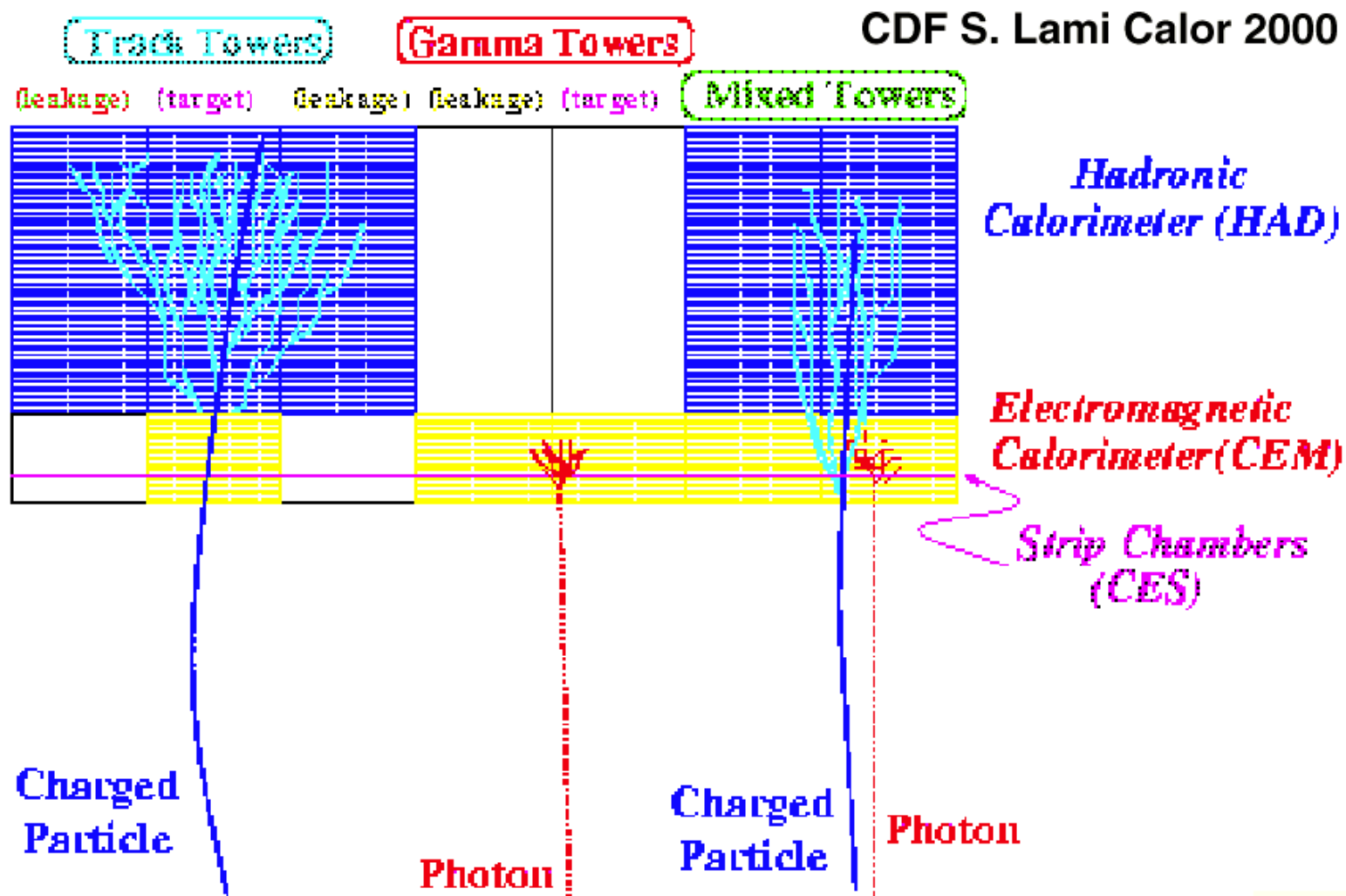
Offline – calorimeter plus fully reco-ed tracks

- **Resolution improvement**
- **Fake jets/Pileup jets rejection**
  - → Jet and MET will be reconstructed with Tracks, EM clusters and HAD clusters.
  - → All tracks down to $E_T \sim 700\text{MeV}$ have to be reconstructed at 10E34!
- **Physics correction – e.g. correction for IFR/FSR.**
  - → In-situ calibration!

CDF S. Lami Calor 2000
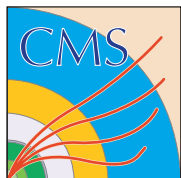
Improvement of jet energy resolution with tracks

The work initiated by Dan Green in CMS and continued by Irina Vardanian.

Long way to go, but promising…
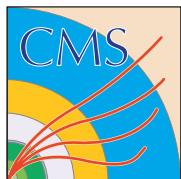
Software (1)

Simulation

- **CMSIM**
  - 120 – mainly used (2000 fall production)
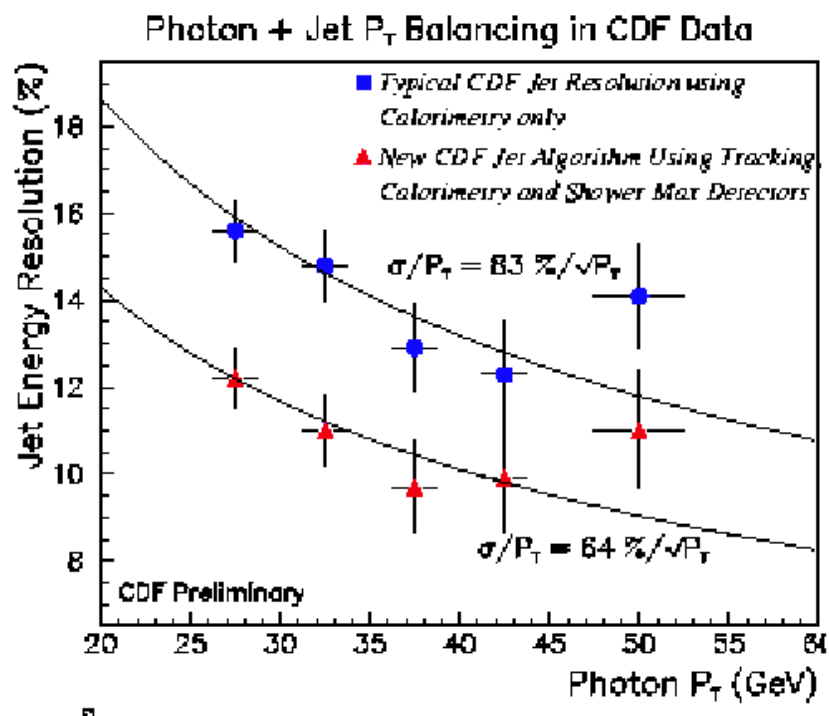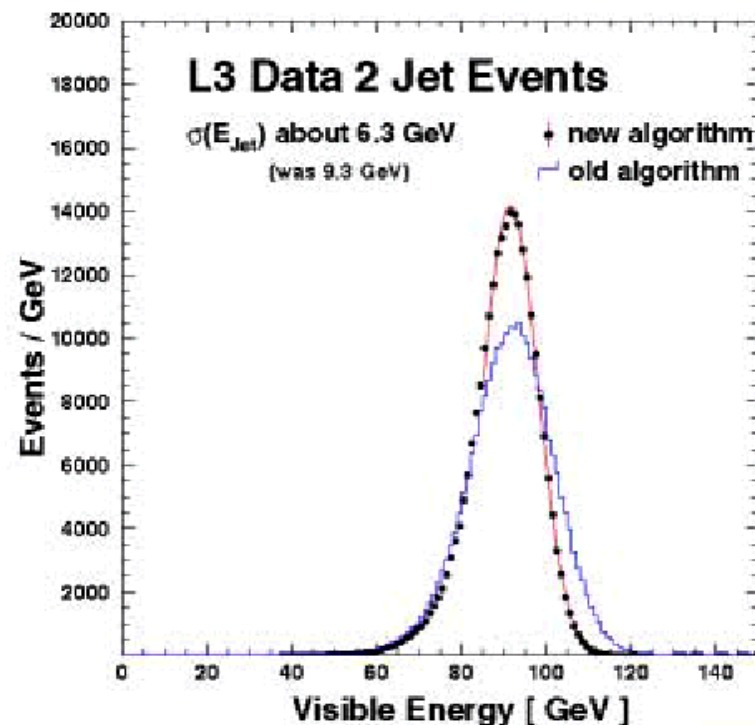   - **Default - GHEISHA**
  - 121 – for muon (new 3D field map)
    - **Default – GCALOR**
  - 122 – updated tracker (just released)
    - **HF updated (?) – V.Kolosov**
- **OSCAR (GEANT4)**
  - Geometry
    - **Almost there - Sunanda Banerjee**
  - Interface to ORCA (hits)
    - **almost there ???**
  - Validation of physics in G4
    - **'96 test beam - Sudeshna Banerjee**
- **Validation – from CMSIM/OSCAR to ORCA**
  - **Just started - Shashi Dugad**
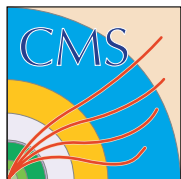
Software (2)

Reconstruction

- **Readout simulation (S.Abdullin)**
  - Update/study in progress
- **Jet (H-P.Wellisch)**
  - New addition – Window algorithm (Irina/Olga)
- **MET (P.Hidas)**
- **Tau (A.Nikitenko)**
- **Ntuple-maker (P.Hidas)**
  - New format coming
- **Interface to calibration database (A.Oulianov)**
  - Coming…

Analysis software

- **PAW**
- **Inside ORCA**
- **CAFÉ – first trial version this fall (?)**

Expanding group

We try to attract more people in the HCAL community and help them to get familiar with the CMS detector, CMS software and physics (analysis) at the LHC.

Assumption:
- geographical spread and diversity in skill level continue.

Strategy:
- lower the threshold for entering software development and data analysis.
- build a core software team for strong support (preferably in US).
- recruit experienced people to coordinate larger number of people.

Potential manpower:
- Universities in US, RDMS (not only ITEP an MSU), India, Turkey, Hungary…
- US CMS Software and Computing Project (Tier1 & CAS)
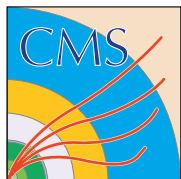
Action Plan

(as of Feb.2001)

Establish the MC data production center in the US (FNAL) in addition to CERN (and Moscow).

Addition
-UCSD
-Florida

- production crew in addition to computer/software system.

Package a complete set of software (OS, compiler, CERNLIB, CMSIM, LHC++, Objectivity, ORCA, OSCAR, SCRAM) and MC events on a hard disk and/or CD's and distribute.

2 gone (Tata,TTU)
3 soon (Kharkov, Panjab, Cukurova)
+ CD by S.Wynhof

- "plug-in & play" on a PC or a laptop (Linux).
  (in addition to network based distribution)

Establish a data analysis environment within C++/OO world.

30GB

- C++/objectivity/ORCA based
  (in addition to PAW-ntuple based analysis environment.)

Enhance communication/collaboration between offline software group, online control/monitor group and hardware group.

- meetings during March CMS week.
  (3/03 on FE, 3/05 On Calibration & Monitoring)
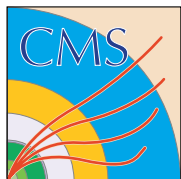
Identify at least two C++/OO experts in each region to help other people in the region.

- CERN (Abdullin, Nikitenko)   - US (Hidas(?), ?)
- Moscow (Krokhotine, Oulianov, OK) - India (SnBanerjee(?), Mohanty(?))

We need urgently

- **Strong software support group**

- **C++ experts**

- **Experienced people to guide other people (analysis, experiment)**

On going physics analyses
(as far as I know)

Higgs (SM/SUSY)
- WH   ($\rightarrow$bb)
- ttH   ($\rightarrow$bb)
- qqH ($\rightarrow\tau\tau$, WW, invisible)
- H/A ($\rightarrow\tau\tau$)
- H   ($\rightarrow$WW, ZZ)
- tbH$^+$ ($\rightarrow\tau\nu$)

SUSY search
- ???

Standard Model
- tt
- single top
- ???

Heavy ion
- ???

In-situ calibration
- γj
- γZ
- tt
- ???

Need a full list !